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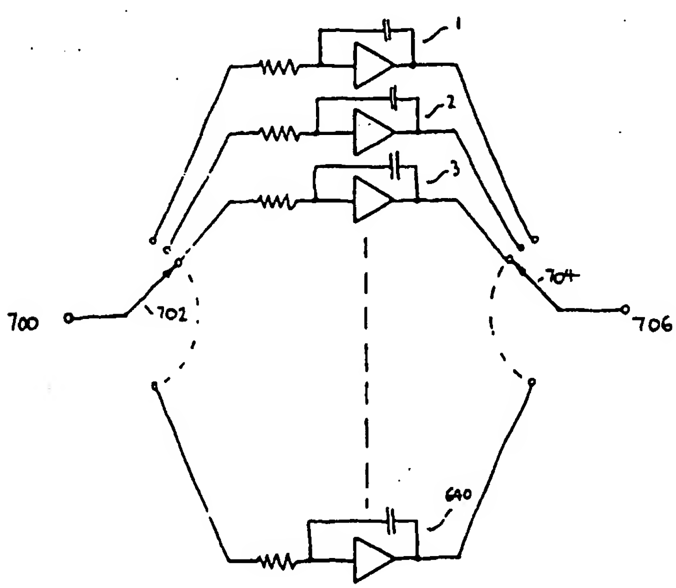
(54) **Vehicle location system**

(57) A system for position-finding of vehicles, based on trilateration using the line synchronising pulses of television broadcast signals. Each vehicle is equipped to receive the synchronising pulses from three or more separate transmitters. The phase shifts between the received pulses are used to derive hyperbolic co-ordinates which are transmitted to a control station where the geographical location of the vehicle may be plotted. Recovery of weak signals from distant sources is achieved by signal processing using a commutating filter (Fig. 1) to time average the received signal over several seconds. The transmitted pulse signals are monitored at the control station for discontinuities due to link failures.



The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982

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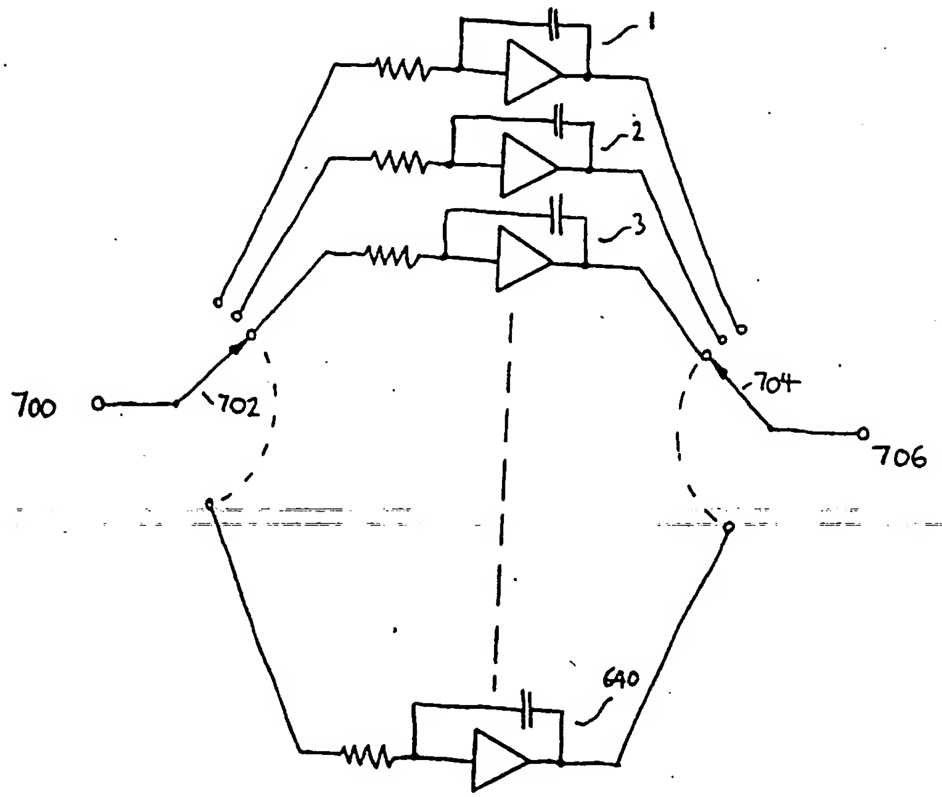

Fig. 1

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VEHICLE LOCATION SYSTEM

The present invention relates to position-finding systems and in particular to those for location and management of fleets of vehicles.

Such location and management systems may be used by police forces, taxi cab companies and others who operate fleets of vehicles. A dispatcher or dispatch computer can select the nearest available vehicle to a desired destination thus reducing the time taken to respond to calls and increasing the overall efficiency of fleet operations.

There are a number of currently known vehicle location systems, each having a number of inherent problems of implementation or operation. The required accuracy of location for such systems is approximately equal to the average distance between vehicles in the fleet. In an urban environment, figures of 150-400 metres have been suggested as a suitable target accuracy. Those systems using passive or active electronic signposts or beacons can achieve required accuracies but such a purpose-built network of signposts would require a vast initial outlay before the first vehicle could use the system.

Various systems of radiolocation are known including triangulation using direction findings either from the vehicle or from fixed sites (e.g. Airborne ADF and VOR, and Marine RDF). The low frequency direction-finding systems (ADF, RDF) suffer from large angular errors due to diffraction of the radio wave front in urban areas and from absorption and interference. Positional accuracy is therefore unacceptably poor. The high frequency system (VOR) is established for aircraft use and beacon locations are invariably such that urban areas are not covered at ground level. Other systems are known which use trilateration based on pulse or phase information, either at low frequencies (e.g. Omega, Differential Omega, Decca and Loran C) or higher frequencies (Airborne DME, Transit Satellite, GPS). These systems based on trilateration are designed primarily for airborne and marine uses and in urban areas they encounter a number of problems. The lower frequency systems using existing networks (Omega, Loran C, Decca)

suffer distortion and attenuati n, whilst higher frequency systems (airborne DME and satellite methods) have problems with line-of-sight considerations and low signal strength. These problems preclude the use of such systems in an urban environment since they seriously affect the attainable target accuracy. United Kingdom patent GB 958,579 describes a radio navigation system using trilateration techniques which uses existing telegraph signals, modified at transmission to phase stabilise a prominent frequency component thereof. United Kingdom patent application GB 2,013,062A describes a system based on trilateration which uses the broadcast signals transmitted by national radio (or television) networks.

For such a system, a single broadcast transmission can only be used if an absolute on-board timing reference of the required precision (better than one microsecond) is available and the form of the video broadcast signal is known. If two transmissions from known locations and of known relative timing are received, the time difference can be used to plot a hyperbola on which the receiver lies (if only two-dimensional location is required). When a third such transmission is received, a second (and third) hyperbola may be plotted, the point(s) of intersection with the first indicating the position of the receiver relative to the known positions of the transmitters.

The geographical areas in which the system of GB 2,013,062A may be used are severely limited since most locations will not be covered by the required three transmitters. Additionally, the complexity and cost of the equipment necessary for monitoring three constantly varying video signals (even if all carrying the same information) and calculating received phase differences would be very high.

In accordance with the present invention there is provided a method and apparatus for position-finding for moving bodies, in which the body receives at least three high frequency pulse signals, each of the signals being transmitted from a separate location, there being a constant phase relationship between the pulse signals at transmission, whereby the vehicle position is derived from the phase shift between the signals when received by the body, and in which each of the high frequency pulse signals has a substantially

constant amplitude.

We have appreciated that suitable high frequency pulse signals already exist in the form of the line synchronising pulses which accompany television broadcast signals. These high power transmissions (of the order of one megawatt) from antennas at heights of 200-300 metres have low scattering and absorption losses and good coverage with regard to line-of-sight constraints. The use of UHF signals (which are known to penetrate buildings more readily than VHF and lower frequencies) is another benefit: video bandwidths of currently known and used UHF television transmissions being 5.5MHz in an 8MHz channel spacing.

The line synchronising pulses have a greater amplitude than any of the chrominance or luminance signals in the video waveform. By use of time-averaging and suitable signal processing, the pulses may be detected at far greater ranges than the remainder of the waveform, thus overcoming the problems of coverage.

One particular embodiment of the invention will now be described by way of example with reference to the accompanying drawing in which:

Fig. 1 shows a commutating filter for processing of the received signal.

In a vehicle location system, each vehicle of the fleet is fitted with a receiver tuned to detect the line synchronising pulses which are transmitted as part of the broadcast signal from a pre-selected television channel. To minimise discontinuities in the calculated position, the television channel chosen is that carrying the least regional variation in programmes. In the United Kingdom, the BBC 2 network is the most suitable.

The line synchronising pulses are repeated at 15.625 kHz and are pulses of maximum carrier amplitude of duration 4.7 microseconds (U.K. Broadcast standards) not being exceded by any of the chrominance or luminance signals. For vehicle speeds of 70 mph (approximately 30 m/s) it is clear that a target resolution of 150-400m represents several seconds of elapsed time. By using signal processing techniques based on tracking time-domain filters to average many thousands of synchronising pulses (e.g. 78,125 over 5 seconds), usable information may be extracted from signals many

times w aker than are required for television service.

One method of processing the received signal is to use a commutating filter as shown in Fig.1. The use of such a filter retains the time domain resolution for accuracy in phase measurement whilst integrating over several seconds to improve the signal to noise ratio.

Referring now to Fig.1, the input signal 700 is sequentially applied, by means of a commutator 702, to a number of integrators 1, 2, 3....640, dwelling on each integrator for 0.1 microseconds and completing a full cycle of 640 integrators in 64 microseconds (the period of the television line). Those integrators sampling the video parts of the line will "smear" the video signals from successive lines, generating an averaged signal which is meaningless and is ignored. Those integrators sampling the synchronising pulse and its neighbouring front and back porches (which are constant from line to line) reinforce the signal to noise ratio by integrating over many thousands of lines.

A second commutator 704, operating in phase with the first, connects the outputs of the integrators 1-640 to an output point 706. The reconstructed video signal at this point consists of the synchronising pulses with a signal to noise ratio improved in proportion to the square root of the number of lines integrated whilst retaining a time resolution of 0.1 microseconds, together with the averaged video signal. A practical implementation of the circuit can be made using a charge-coupled "bucket-brigade" device.

In the steady state, any one integrator samples the same 0.1 microsecond part of successive television lines. Therefore, since the synchronising pulses represent a small part of the total video line duration, and the video portion of the line is ignored, it is clear that most of the integrators 1-640 need not exist provided that the phase of the two commutators 702, 704 can be adjusted to match the incoming video in such a way that the sync pulse part of the video waveform is sampled by the real integrators. This could be achieved by a search and track procedure under control of a microprocessor.

If the pulse to pulse noise is uncorrelated, for 5 seconds

averaging, an impr vement in signal to n ise ratio of approximately 280 times is achieved. Assuming an inverse fourth power law for UHF radio propagation over typical terrain, the signal improvement of 280 times corresponds to a range increase of approximately four times. It is thus the case that, in general, all locations will be able to receive the requisite number of stations for successful trilateration. The only limitation for the system may arise due to interference through frequency re-use. Examination of the frequency plan for the United Kingdom suggests that this is not a significant obstacle.

To accommodate periodic discontinuities (due to link failures and consequent re-routing of the signal to the transmitter) in the relative phase of the transmitted signals, a control station is provided which monitors the various television signals. Each vehicle in the fleet is in communication with the control station, transmitting to it the dynamic hyperbolic co-ordinates derived from the phase shift between received pulse signals. Using the observed instantaneous phase relationships between transmitted and received pulse signals, the geographical location of the vehicle may be plotted. By monitoring the transmitted signals, any changes in relative phase between transmitters would be accounted for in the calculations, introducing at worst only a momentary uncertainty in the reported vehicle location. Implementing such a system as this, based on the repetative line synchronising pulses of television broadcasts and using signal processing techniques to recover weak signals, would be a far simpler matter than for many suggested systems and would provide wider coverage with no increase in complexity.

CLAIMS:

1/ A method of position-finding for moving bodies, in which the body receives at least three high frequency pulse signals, each of the signals being transmitted from a separate location, there being a constant phase relationship between the pulse signals at transmission, whereby the body position is derived from the phase shift between the signals when received by the body, and in which each of the high frequency pulse signals has a substantially constant amplitude.

2. A method of position-finding according to claim 1 in which the body position is derived at a control station remote from the body, the control station monitoring the transmitted pulse signals and the phase shift values which are transmitted to the control station from the body.

3. A method of position-finding according to claim 1 or 2 in which the transmitted pulse signals are in the U.H.F. band.

4. A method of position-finding according to any of claims 1 to 3 in which the high frequency pulse signals received are the synchronising pulses accompanying television broadcast signals.

5. A method of position-finding according to claim 4 in which each of the television broadcast signals is carrying the same television channel.

6. A method of position-finding according to claim 5 in which the television channel selected is that which carries the least variation in regional programming.

7. A method of position-finding according to any previous claim in which signal processing techniques are used to produce a time-averaged value for the phase shift between signals received by the body.

8. Apparatus for position-finding for moving bodies comprising means carried by the body to receive at least three high-frequency pulse signals, the signals having substantially constant amplitudes and phase relationship and being each transmitted from a separate location, and means for deriving the body position based on the phase shift between the received signals.

9. Apparatus according to claim 8 further comprising a control station remote from the body having means for monitoring the sources of the transmitted pulse signals, means for receiving values of the phase shift between pulse signals received at the body and the said means for deriving the body position, the body having means for transmitting the said phase shift values to the control station.

10. Apparatus according to claim 8 or claim 9 in which the means carried by the body to receive the high frequency pulse signals operates the U.H.F. band.

11. Apparatus according to any of claims 8 to 10 in which the means carried by the body to receive the high frequency pulse signals is tuned to receive the synchronising pulses accompanying television broadcasts.

12. Apparatus according to any of claims 8 to 11 including signal processing and filtering means arranged to generate a time averaged value of the phase shift between the received high frequency pulse signals.

13. A method of position-finding substantially as hereinbefore described.

14. Apparatus for position-finding substantially as hereinbefore described with reference to the accompanying drawing.

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